



## Review Article

# Agriculture Policy and Major Areas for Research and Development in Bangladesh

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**Abstract** | Since gaining independence, Bangladesh's agricultural sector has made significant strides in production and yield, ensuring food self-sufficiency through the adoption of advanced technologies and policy improvements. However, despite these progressions, the sector still faces considerable challenges, including climate change, land shortage, and ecosystem stresses. These pressing issues necessitate the implementation of robust agricultural policies and focused research and development (R and D) across the crops, fisheries, and livestock sectors to maintain food security. This review aims to examine the current state of agricultural policies and R and D, highlighting crucial areas for future R and D within the crops, fisheries, and livestock sectors. It is noteworthy that existing policies primarily favour producers and agro-entrepreneurs. The government has implemented several measures to incentivize and stimulate the growth of the overall agricultural sector. An examination of the broader agricultural sectors crops, fisheries, and livestock over the past two years (2021-2022) indicates that yield and production have remained stable. This suggests a need to adapt R and D strategies in order to stimulate growth in certain sub-sectors and reduce reliance on food and produce imports. Key R and D areas in the crop sectors include protecting arable land, implementing appropriate climate change strategies, improving fertilizer, water, and pest management, ensuring seed quality, developing a sustainable and dependable supply chain for producers and consumers, and allocating an adequate R and D budget. Finally, to eradicate hunger and malnutrition and ensure sustained food security, it is essential to address problems at the grassroots level, rather than focusing solely on R and D. Emphasizing grassroots solutions can pave the way to a more resilient and self-sufficient agricultural sector.

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## Introduction

Since its independence in 1971, Bangladesh has made significant strides in economic and social development. Over the past decade (2010–2020), the economy has grown, and poverty levels have declined by roughly a third. Despite being one of the most densely populated countries globally (World Bank, 2015), Bangladesh continues to grapple with numerous political, social, economic, and environmental challenges, including political instability, corruption, poverty, and overpopulation. Agriculture plays a pivotal role in Bangladesh's economy, serving as a primary food source, a means of livelihood, a catalyst for development, and a major employment sector. Approximately 50% of the country's workforce is engaged in this sector (Rahman, 2017). In 1971, agriculture contributed over 60% to the GDP (FAO, 2011), but this figure has dramatically declined to 12.09% (BBS, 2022) due to structural transformation processes. The country's agricultural growth has been hampered by consistent loss of cropland, the adoption and diffusion of new technologies, and insufficient funding for agricultural extension and research activities. As the country's staple food, rice production is of utmost importance to Bangladesh's food security (Rahman *et al.*, 2022). Thanks to the development of short-duration, high-yielding, stress-tolerant, resource-responsive, and semi-dwarf cultivars, rice production has more than doubled in the last 30 years (Chowhan *et al.*, 2021). The people of Bangladesh heavily rely on fish and fisheries for sustenance, income, and lifestyle. According to the BBS (BBS, 2022), this industry contributes 2.59% to the GDP and 22.2% to the Agri-GDP. It directly employs approximately 1.25 million people, with an additional 12 million rural residents benefiting indirectly. Major challenges to food security include loss of arable land, rising sea levels, frequent flooding, and unpredictable weather patterns. Other restricting factors include low productivity and profitability, a high yield gap, slow adoption of new technologies, inadequate private sector investment in the agricultural value chain, fluctuations in agricultural production, and a lack of resources for building climate change resilience (Faisal and Parveen, 2004). Bangladesh experiences six seasons annually, with winter, summer, and monsoon being the most prominent. Winter temperatures fluctuate marginally, ranging from 7°C to 13°C minimum and 24°C to 31°C maximum. The highest recorded

summer temperature is 37°C, occasionally reaching 41°C or higher in some areas. The rainy season, which spans from June to October, accounts for 80% of the annual rainfall, with an average precipitation range of 1429 to 4338 mm (BBS, 2022). Attaining sustainable agricultural development requires the implementation of well-conceived policies, improved management techniques, and successful targeted investments, balanced by policy and political commitments. In this context, prioritizing research-based policies is essential for developing innovative technologies. Considering the factors mentioned above, exhaustive research and development programs across various agricultural subsectors are deemed necessary to devise practical solutions for food and nutrition security in Bangladesh. This paper scrutinizes current agricultural policies, assesses R and D in key sectors, and identifies future directions for assuring sustainable food security in Bangladesh.

## Materials and Methods

This article is primarily based on secondary data, drawing from various published papers, periodicals, and book reviews. The data was predominantly sourced from databases including Scopus, Web of Science, and specific journals focused on agriculture and development studies. Initially, around 80 articles and reports were collected, from which 35 were selected based on their relevance to form the foundation of this review. This article serves as a comprehensive review paper, developed through an amalgamation of internet searches, in-depth analyses of articles across diverse journals, books, and proceedings obtained from the libraries of agricultural universities (BAU, BSMRAU), academies (NATA), and research institutions (BARI, BRRI, BINA, BLRI, BFRI, BARC). Additionally, the Department of Agricultural Extension (DAE) contributed supplementary data sources, which were integrated with other pertinent data to enrich this study.

### *Agricultural policy*

In Bangladesh, agriculture employs 40.6% of the workforce and contributes 12.09% to the nation's GDP (Table 1). The population is expanding at an average annual rate of 1.22, with the population density per square kilometer increasing from 976 in 2011 to 1119 in 2022. Predominantly rural, 76.75% of Bangladesh's population resides in villages, where the majority (51.7% of the labor force) engage in agriculture (BBS,

2022) at a subsistence level (Chowhan, 2021). Given the country's low land-to-person ratio, achieving food security presents a significant challenge (Rahman and Salim, 2013). To reform the agricultural sector, Bangladesh has implemented several policies aimed at technological advancement, poverty reduction, and improved living standards for its growing population. The adoption of high-yielding varieties (HYV) of rice technology began in the early 1960s, facilitated by the use of modern inputs such as pesticides, chemical fertilizers, irrigation systems, financial assistance, goods procurement, storage, and marketing services. However, changes in law aimed at expanding agricultural input supply and reducing import duties on farm machinery led to fluctuations in the acceptance of HYV technology during the 1970s, 1980s, and late 1980s. As a result, irrigation coverage saw a significant increase, from 22.5% of the gross cultivated area in 1980-1981 to 51.5% in 2000-2001 (Kumar *et al.*, 2008). Starting in the 1990s, a series of policies were gradually implemented to ensure the long-term availability of food grains and bolster food security. However, these objectives have not been fully achieved as the nation still occasionally faces food deficits (Alam *et al.*, 2011). To meet the food requirements of the ever-growing population, it is crucial to focus on enhancing agricultural production and developing expertise. The continued development of agricultural production and expertise is essential to meet the food requirements of Bangladesh's rapidly growing population. Therefore, the country's efforts towards achieving sustainable agricultural development must incorporate well-thought-out policies, improved management techniques, and targeted investments, all supported by political commitment. In light of the factors mentioned above, comprehensive research and development programs across various agricultural subsectors are considered necessary to devise practical solutions for food and nutrition security in Bangladesh. This paper examines the current agricultural policies, assesses R and D in key sectors, and identifies future directions for ensuring sustainable food security in Bangladesh.

#### *Policy and program evaluation in agriculture*

**Policy decisions aimed at producers:** Over the past three decades, achieving rice self-sufficiency has been the key focus of Bangladesh's agricultural and food security policy. As a result, the Government of Bangladesh (GoB) has implemented measures to directly assist farmers, including promoting the

use of agricultural inputs, expanding access to credit options, and ensuring support prices through public procurement.

**Increasing fertilizer subsidies:** In recent years, fertilizers have garnered significant attention, particularly due to initiatives like the agriculture input assistance card program launched by the Government of Bangladesh (GoB) in 2010. Under this scheme, participating farmers receive a smart card enabling them to link a bank account for direct payments towards purchasing inputs. The expenditure on fertilizer subsidies has shown a consistent upward trend, increasing from 35 billion (US\$ 503 million) in 2007-2008. Over the 13-year period from 2008-09 to 2020-21, the government allocated over Tk 820 billion solely to subsidize the agricultural sector. According to [The Business Standard \(2022a\)](#), in the fiscal year 2020-21, Taka 77 billion was allocated for fertilizer subsidies. The projected fertilizer requirement for the fiscal year 2022-2023 is estimated at 6.3 million tons, including 2.6 million tons of urea, 1.5 million tons of DAP, 0.7 million tons of TSP, 0.75 million tons of MOP, and 0.55 million tons of gypsum. Notably, in the fiscal year 2022-2023, government spending on fertilizer subsidies surged significantly, reaching Tk 300 billion (Khatun *et al.*, 2022).

**Increased loan availability to smallholder farmers:** Credit to the agricultural sector has emerged as a key government strategy in response to global financial and food crises. All scheduled banks were mandated to disburse TK 28,391.00 crore of agricultural credit by the end of FY22, representing a 7.98% increase over the projected TK 26,292.00 crore for FY21 and an 11.29% rise over the actual disbursement of TK 25,511.25 crore in FY21 (Bangladesh Bank, 2022). The Bangladesh Bank issued directives to commercial banks to fulfil the working capital needs of small farmers, with the government urging banks to enhance farm loans (which constitute about 6% of total loans) and make agricultural lending compulsory for all banks to stimulate agricultural production and diversity. Additionally, the government reduced the interest rate on loans from 8% to 2% to incentivize the cultivation of pulses, oilseeds, and spices.

**Stability of prices over time and local procurement:** In order to provide farmers with pricing and profit incentives while ensuring food accessibility for all consumers, the Government of Bangladesh (GoB)

manages public food stocks. Bangladesh is expanding its food grain storage capacity to 3.5 million tons, up from the current 2.18 million tons (Dhaka Tribune, 2023). This increase in storage capacity aligns with the national social security strategy, which aims to use public resources for emergency assistance services and integrate food transfers with cash transfers as needed.

**Diversification of food and agriculture:** Agricultural diversification is a primary objective of Bangladesh's agricultural strategy, aiming to ensure profitability, sustainability, and competitiveness in the sector (Tabassum and Rezwana, 2021). Increasing crop variety is essential to boost production, enhance nutritional security, maintain soil health, and elevate farmers' income. The 2018 national agricultural policy emphasizes crop diversity, encompassing potatoes, vegetables, fruits, legumes, oilseeds, and spices through a dedicated diversification program. Bangladesh's national food and nutritional security strategy for 2021-2030 targets nutrition-sensitive diets, resilient crops, social protection, coordination, and public participation. The 2007 national livestock development policy aims to alleviate rural poverty by enhancing milk, meat, and egg productivity, focusing on processing and value addition. The 2013 national livestock extension policy addresses veterinary concerns related to public health and food safety, supports producer groups, enhances extension services, strengthens research-extension linkages, and addresses challenges faced by smallholder livestock farmers. Similarly, the National Fisheries Policy of 1998 seeks to augment fisheries resources and production, reduce poverty by empowering fishermen to be self-reliant, improve their socioeconomic status, meet the demand for animal protein, promote economic growth, and earn foreign exchange through fish and related food exports.

**Consumer focused policy choices:** The GoB employs two primary strategies to enhance food access: temporary measures known as social safety net programs, primarily aimed at alleviating immediate hardship by distributing food or cash, and long-term policies and programs designed to boost the incomes of the disadvantaged through employment-generating activities (Barkat-e-Khuda, 2011). Although these programs were initiated in the mid-1970s, they have undergone significant evolution since then, transitioning from relief-oriented to development-focused initiatives. Moreover, there has been a shift

from simply reducing ration prices to targeted food distribution and/or conditional cash transfers.

**Cereal food distribution system for public:** The Government of Bangladesh (GoB) provides immediate assistance during natural disasters, addresses persistent hunger through targeted food distributions, and stabilizes food prices in the market, particularly for rice. To ensure food security, the GoB engages in government-to-government agreements to procure rice and wheat directly from farmers. Food distribution occurs through two channels: non-monetized programs, which involve targeted safety net initiatives without sales transactions, and subsidized food sales (Open Market Sales), where rice and wheat are sold as part of the public food grain distribution system. Directorate of food procures and stores grain, primarily utilizing the Public Food Distribution System (PFDS), with over 90% of rice stored in the private sector. The remaining five to ten percent is stored in public facilities, and a significant portion of private sector storage is managed by farmers on their own farms (Chowdhury *et al.*, 2021).

**Improved incentives and diversification of exports:** In its National Industrial Policy 2022, the Government of Bangladesh (GoB) identified manufacturing and agriculture/food processing as viable sectors for diversifying exports (JICA, 2023). Additionally, the government has introduced an export policy aimed at prioritizing and achieving diversification in agricultural exports. Under the new export strategy, farmers will be exempt from duties and value-added tax (VAT), which is expected to boost agricultural output and aid Bangladesh in achieving middle-income status by 2021. The policy proposes tax incentives and credit facilities to revitalize the shrimp and fish export sectors, including bank working capital loans for shrimp exporters at a 9% interest rate. The tea industry is highlighted as a promising new area for export expansion, with exports projected to increase from the current \$66 million annually to \$100 million. The export policy also identifies agro and herbal products as emerging sectors (CEIC, 2023).

*Current scenario of research and development in agriculture*

With 16.06 million hectares (39,678,000 acres) of cropland, agriculture stands as the largest sector contributing to Bangladesh's economy, accounting for 12.09% of the GDP (Table 1). The development of

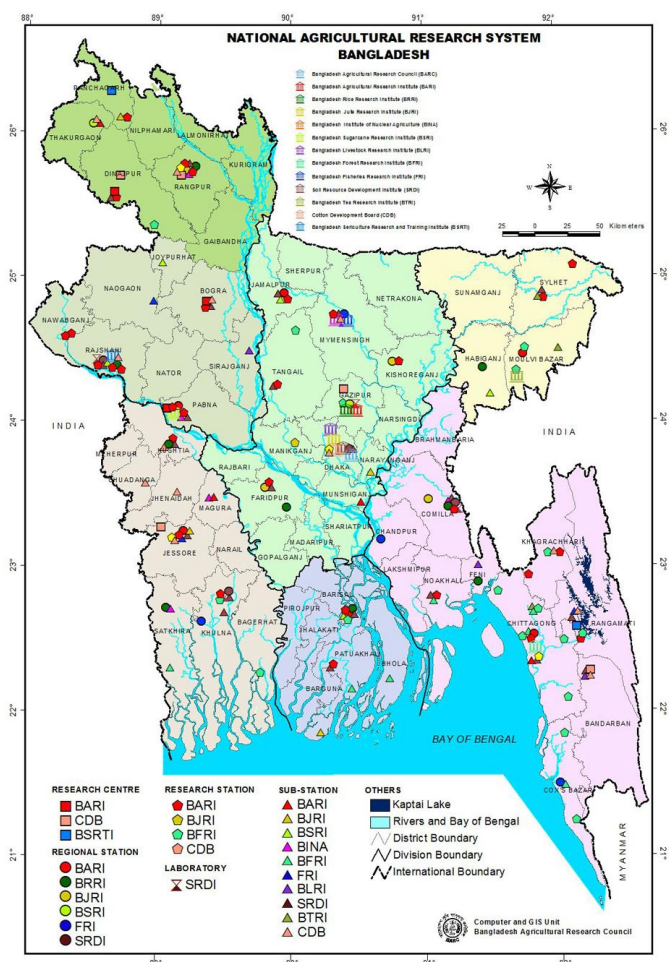
**Table 1: Statistics on Bangladesh agriculture.**

<b>Dwelling Households (no): 35533180</b>	<b>Agriculture Farm Households (no): 16562974</b>
Total area (acre): 36465000	Single cropped area (acre): 5216000
Not available for cultivation area (acre): 8284000	Double cropped area (acre): 10194000
Cultivable waste area (acre): 671000	Triple cropped area (acre): 4613000
Current fallow area (acre): 1066000	Quadruple cropped area (acre): 56000
Cropping intensity (%): 198	Net cropped area (acre): 20081000
Contribution of agriculture to GDP (%): 12.09	Gross cropped area (acre): 39678000

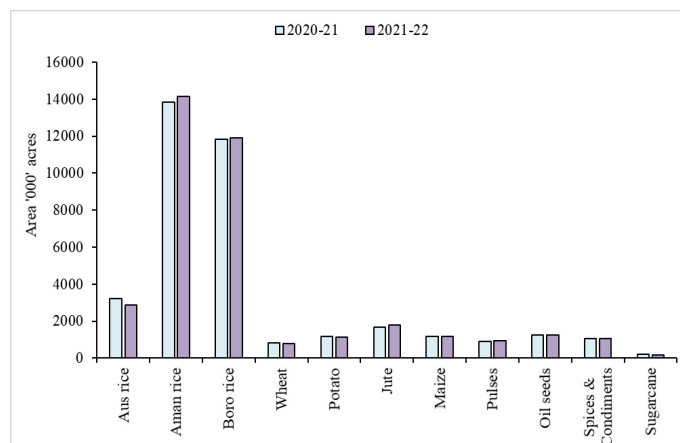
Source: YAS (2021).

new agricultural technologies (R and D) is overseen by the national agricultural research system (NARS), governed by the Bangladesh Agricultural Research Council (BARC) (Figure 1). Additionally, innovation and technological advancements in agriculture can also be pursued by individual researchers and the private sector.

substantial losses of both food and cash crops. Rice, maize, jute, sugarcane, potatoes, legumes, oilseeds, wheat, spices, tea, and tobacco are among Bangladesh's principal crops. The government's key policies include promoting crop diversification, facilitating loans, conducting extension work, supporting research, and distributing agricultural inputs. Currently, Bangladesh is close to achieving self-sufficiency in food grain production. In the 2021-22 period, there was a significant expansion in the area dedicated to key cereal crops, particularly *aman* and *boro* rice, while the *aus* rice area decreased notably (Figure 2). Although the cultivation area for oilseeds, jute, and pulses saw marginal growth, the areas for wheat, potato, maize, spices, condiments, and sugarcane witnessed declines (BBS, 2022).



**Figure 1: Location of NARS institute/organizations in Bangladesh (BARC, 2023).**



**Figure 2: Area under different major crops (BBS, 2022).**

**Crops:** Crops play a crucial role in Bangladesh's agriculture, contributing approximately 5.64% to the country's GDP (BBS, 2022). Natural disasters such as floods, cyclones, and droughts often result in

Even with challenges such as shrinking arable land, increasing population demands for food and nutrition, climate change impacts, the Russia-Ukraine crisis, and the COVID-19 pandemic, Bangladesh has sustained agricultural production and ensured food security through adoption of agriculture-friendly policies and strategies (Bangladesh Economic Review, 2023; Chowhan, 2022). Notably, the 2021-22 period saw a significant boost in the production of main cereal crops, driven by increased output of Aman and Boro rice

(Figure 3). Modern varieties developed by institutions like the Bangladesh Rice Research Institute (BRRI) and Bangladesh Institute of Nuclear Agriculture (BINA) account for over 85% of rice cultivated in Bangladesh (Chowhan *et al.*, 2021), contributing to higher grain yields and increased production. Despite Bangladesh's reliance on food imports, particularly wheat, alongside rice, sugar, and edible oil (Table 2), the adoption of high-yielding varieties has helped maintain relatively stable production levels for potatoes, jute, pulses, oilseeds, spices, condiments, and maize, while wheat and sugarcane cultivation areas have declined. Furthermore, various natural disasters, including floods, heavy rains, flash floods, water surges, cyclones, tornadoes, hailstorms, and tidal bores, have affected the cultivation areas and production of Aus rice and other crops.

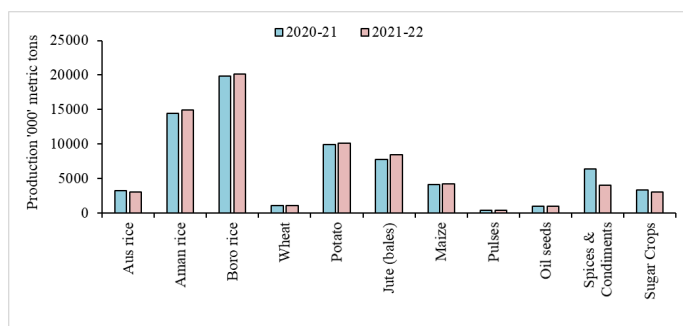


Figure 3: Production of different major crops (BBS, 2022).

Table 2: Import of agricultural products.

Commodity	('000' BDT)			
	2018-19	2019-20	2020-21	2021-22
Rice	10113281	1990757	75552440	37970653
Wheat	123625351	142901568	162928635	193775326
Maize	26565458	28590301	48232374	61411497
Soybean oil	114490388	81219127	111819513	169855596
Palm oil	132339151	152879778	186823760	283677394

Source: (BBS, 2022).

**Horticulture:** In terms of olericulture, brinjal (eggplant) remains the highest produced vegetable, followed by tomato, cabbage, pumpkin, cauliflower, and radish during the period of 2020-22 (Figure 4). Vegetable production has shown stability or modest increases compared to previous years. In the realm of pomology (fruit cultivation), mango holds the top position among fruit crops, followed by jackfruit, banana, pineapple, and papaya (Figure 5). Notably, jackfruit and ber (Indian jujube) production slightly decreased compared to the previous year (2020-21). The adoption of new high-yielding varieties and

improved cultural practices has led to a sevenfold increase in vegetable production over the last 12 years, positioning Bangladesh as the third-largest global producer of vegetables (The Business Standard, 2022b).

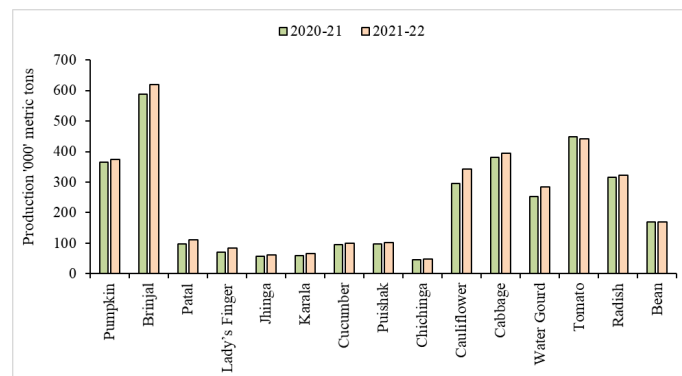


Figure 4: Production of different vegetables (BBS, 2022).

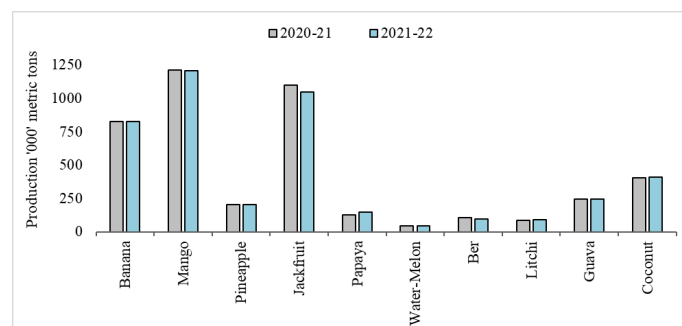


Figure 5: Production of different fruits (BBS, 2022).

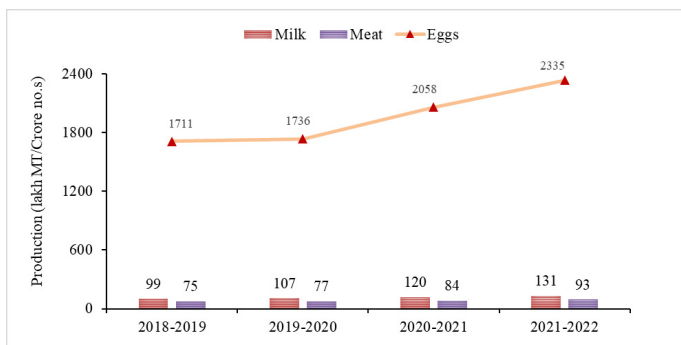
**Livestock:** The livestock sub-sector plays a critical role in Bangladesh's agricultural landscape by supporting crop cultivation, ensuring food security, combating poverty, improving nutrition, and generating employment. Dairy and poultry production, requiring less acreage and being less affected by seasonal variations compared to crops, fisheries, and forestry, offer distinct advantages. However, several challenges hinder livestock productivity, including the lack of suitable breeds, scarcity of high-quality feed and fodder, inadequate technology to improve feed efficiency, insufficient veterinary care, inadequate disease diagnosis technologies, limited epidemiological data on major livestock diseases, absence of a strategic disease control program, inadequate quality control measures, and insufficient preservation technologies. Livestock contributes around 1.76% to the GDP and constitutes 15.09% of the agricultural GDP at current prices, with a growth rate of 6.49% (BBS, 2022). Table 3 presents the current demand, production, and availability estimates based on data from the Department of Livestock Services (DLS, 2023). Milk production is estimated at 13.07 million tons,

**Table 3:** Demand, production and deficiency of milk, meat, and eggs (2021–22).

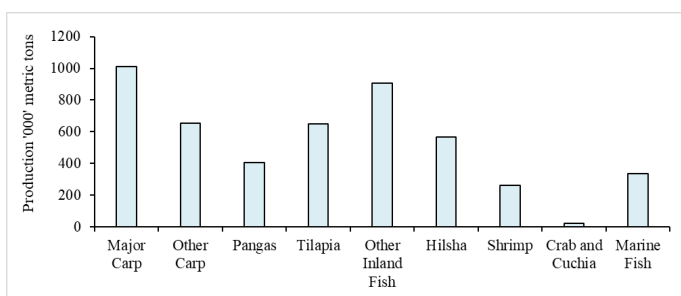
Products	Production	Sufficiency	Availability
Milk	13.07 million tons	16.55% deficient	158.19 (ml/day/head)
Meat	9.27 million tons	Sufficient	122.10 (g/day/head)
Egg	2335.5 Crore numbers	Sufficient	95.27 (eggs/year/head)

Source: DLS (2023).

with an availability of 158.19 ml/day/head, which falls short of the daily requirement of 250 ml/day/head, indicating a 16.55% deficit in milk production. Meat production stands at approximately 9.27 million tons, providing an availability of 122.10 g/day/head against a daily requirement of 120 g/day/head. Egg availability is reported at 95.27 eggs/year/head, with a total production of 2335.5 crore eggs. Although current meat and egg production meets demand, the growing population poses challenges for sustaining these levels. Over the years, there has been an increasing trend in milk, meat, and egg production (Figure 6). However, addressing the growing demand and ensuring adequate supply remain key priorities for the livestock sector in Bangladesh.



**Figure 6:** Production of milk, meat, and eggs (BBS, 2022).



**Figure 7:** Production of different species of fisheries (BBS, 2022).

**Fisheries:** Bangladesh boasts abundant fishery resources, with numerous rivers, canals, tanks, and low-lying areas, including paddy fields covering nearly 12 million acres that remain flooded for about half of the year, providing habitats for a diverse range of tropical fish species. Fish, along with rice, form the staple diet of the typical Bangladeshi. Hilsa, lobsters, and prawns are among the fish species exported to other countries,

benefiting from the country’s strategic location along the southern Bay of Bengal. The fishing industry contributes approximately 2.59% to Bangladesh’s GDP at current prices (BBS, 2022). While the fishing industry experienced a higher gross value growth rate than the agriculture sector in previous years, this trend has moderated recently (BBS, 2022), with fish production increasing from 38.78 lakh tons in 2015–16 to 47.59 lakh MT in 2021–22 (Table 4). Major carp is the primary fish cultivated in Bangladesh, followed by other inland species, Tilapia, and Hilsa (Figure 7). Fish and fishery products are major export commodities for Bangladesh, with exports reaching 54,995 MT valued at 3545.32 crore Taka in 2020–21 (Table 5).

**Table 4:** Sector-wise fish production in inland and marine fisheries (2021–22).

Sector of fisheries	Water area (Hectare)	Pro-duction (Mt)	% of pro-duction
<b>A. Inland Open Water (Capture)</b>			
River and Estuary	853863	342545	7.20
Sundarbans	177700	24259	0.51
Beels	114161	105573	2.22
Kaptai Lake	68800	17937	0.38
Floodplain	2646248	831317	17.47
Total capture fishes	3860772	1321631	27.78
<b>Inland Closed Water (Culture)</b>			
Pond	410683	2166715	45.58
Seasonal cultured water body	149004	231692	4.87
Baor	5671	11685	0.24
Shrimp/Prawn Farm	262980	287497	6.04
Crab	9353	13397	0.28
Pen Culture	7708	15063	0.32
Cage Culture	1.75 lakh m <sup>3</sup>	5021	0.11
Total Culture Fishes	845399	2731070	57.39
Total Inland Fisheries	4706171	4052701	85.17
<b>B. Marine Fisheries</b>			
Industrial (Trawl)		137170	2.88
Artisanal		568860	11.95
Total Marine Fisheries		706030	14.83
Total Production in Bangladesh		4758731	100.00

Source: BBS (2022).

**Table 5:** Annual export of fish and fish product (2020–21).

Fish and fish product	Frozen shrimp/ Prawn	Frozen fish	Dry fish	Dry Salted fish	Crab and Kuchia	Salted fish
Quantity (Kg)	34345911	9584485	4658826	4480084	1841940	83487
Value ('000 Tk)	29371681	3634253	730641	577505	1090352	48786

Source: *BBS (2022)*.

*Priority areas for research and development in Bangladesh*

**Preservation of agricultural land:** It is essential to assess the current land use policy in consultation with relevant professionals, experts, and representatives of farmers, and make necessary amendments based on their feedback. However, in the context of Bangladesh, this type of policy preparation and implementation faces challenges due to issues such as lack of accountability, transparency, corruption, and inefficiencies in public administration ([Chowhan et al., 2023a](#)). To prevent further loss of arable land, immediate implementation of the policy is imperative. Each year, approximately 1% of the total arable land is lost, highlighting the urgency for strict enforcement of the “Protection and Usage of Agricultural Land Act” to safeguard the country against barrenness and food shortages ([The Daily Star, 2019](#)). Arable khas lands should not be allocated for housing purposes as currently planned by the government. Instead, these lands should be distributed to landless farmers exclusively for agricultural use ([Chowhan, 2020](#)).

**Climate change adaptation or mitigation:** Salt tolerant rice varieties like BRRI dhan67, BRRI dhan97, and BRRI dhan99 were developed by the Bangladesh Rice Research Institute (BRRI), while Binadhan-8, Binadhan-10, and Binadhan-23 were developed by the Bangladesh Institute of Nuclear Agriculture (BINA). Additionally, tropicalized wheat varieties were developed by CIMMYT and BARI. The development of strains resistant to salinity, floods, and drought requires biotechnology or gene transfer technology, emphasizing the need for researchers and decision-makers to explore alternative methods to maximize productivity in stress-prone areas ([Rahman et al., 2022](#)). Moreover, there is a scarcity of advanced technologies in fruit, spice, oilseed, and pulse cultivation, necessitating the development of high-yielding varieties (HYVs) in these sectors. Hybrid varieties of rice, vegetables, and other crops are not readily available in the country. Given this scenario, the government should encourage collaboration with the private sector, NGOs, BRRI, BARI, and other National Agricultural Research System (NARS) institutions to establish a national hybrid variety program for

these crops. The government’s national development strategy must prioritize climate change adaptation, particularly addressing issues such as flooding, sea-level rise, and salt intrusion on agricultural land, which require strong political commitment. Possible mitigation strategies include promoting renewable energy, reducing and optimizing fossil fuel use, reforestation, implementing early warning systems for disaster management, and halting deforestation, especially in coastal regions, to preserve green cover and mitigate environmental impacts.

**Fertilizer management:** Chemical fertilizers should be supplemented with organic manures to promote the use of balanced fertilizers, and subsidies for non-urea fertilizers should be maintained. Farmers should gradually reduce their reliance on chemical fertilizers to preserve soil fertility. It is crucial for the government to explicitly emphasize the necessity of balanced fertilizers in its new National Agricultural Policy (NAP) to ensure sustainable agricultural production. The International Federation of Organic Agriculture Movements (IFOAM) operates in 92 countries worldwide. Bangladesh has proposed membership to IFOAM to encourage farmers to adopt organic fertilizers and practices. As the population continues to grow, meeting food demands requires expanding intensive farming using high-yielding cultivars and advanced technologies. Both chemical and organic fertilizers are essential to address the nutritional needs of these high-yielding crops. The increasing use of chemical fertilizers in crop production is aimed at boosting agricultural output to meet rising food demands. However, the predominant practice in Bangladesh’s agriculture remains the use of urea fertilizer alone ([Bangladesh Economic Review, 2023](#)).

**Water management:** Irrigation should be employed at optimal stages of crop growth to maximize water efficiency. Rainfed farming can benefit from practices like relay cropping, mixed cropping, and minimal tillage techniques. Farmers can cultivate wheat, legumes, and other low-water-demand crops for economic reasons. Rainwater harvesting can be utilized for surface irrigation and pond construction



to enhance water availability. Reducing diesel prices or providing subsidies to small and marginal farmers lacking resources can help lower irrigation costs. Key areas for research and technological development include evaluating surface and groundwater resources for agriculture using quantitative and qualitative methods, managing watersheds in hilly regions, rainwater harvesting for agriculture, addressing pollution related to groundwater depletion, improving irrigation water use efficiency, and adopting alternative wetting and drying technologies for major crops and cropping patterns (Ahmed *et al.*, 2012).

**Pest management:** To effectively manage pests, it is crucial to develop more resistant varieties using both traditional breeding methods and biotechnology. Biotechnology and Integrated Pest Management (IPM) principles should also be applied to other economically important crops such as fruits, pulses, spices, and oilseeds. The importance of adopting these advanced and environmentally friendly technologies should be emphasized in the new National Agricultural Policy (NAP). For instance, to manage shoot and fruit borer infestations in brinjal and cucurbits, the Bangladesh Agricultural Research Institute (BARI) has recently developed sex pheromone trap technology. Many diseases have the ability to spread spatially and temporally, making precision farming advantageous (Kachhawa, 2017). Mycoinsecticides have the potential to play a significant role in Integrated Pest Management (IPM) programs for effective and environmentally safe control of insect pests in agricultural production. Promotional campaigns, such as advertisements, exhibitions, and apprenticeship programs, can be implemented to raise consumer awareness about bio stimulants. Improvements in manufacturing, conceptualization, preservation, and surface treatments are necessary to enhance effectiveness, usability, and cost efficiency (Angon *et al.*, 2023).

**Quality seed production:** To achieve the target of a 20-25% seed replacement rate, it is essential to enhance the current seed production capacity at the Bangladesh Agricultural Development Corporation (BADC). The breeder's seed program within the National Agricultural Research System (NARS) institutes should be expanded to support this goal. Moreover, the government should provide financial support to the private sector and NGOs involved in seed production, offering flexible financing terms.

Farmers also require encouragement to adopt high-quality seeds, which can be achieved through comprehensive training programs on seed cultivation, storage, and processing. Agricultural research stations can play a pivotal role by serving as centres for user-oriented training, demonstration, and production of high-quality seeds (Ahmed *et al.*, 2012). This holistic approach will contribute to improving seed quality and ultimately enhance agricultural productivity and sustainability.

**Credit management:** Adequate and timely availability of credit is essential for investors, particularly during periods of resource scarcity and uncertainty. According to the National Agricultural Policy (1999), the proposed "Agricultural Credit Foundation" aims to address the loan requirements of marginal and small-scale farmers, modelled after the successful "Palli Karmo Sahayak Foundation" (PKSF). To facilitate credit provision to farmers without requiring collateral, it is imperative to establish a dedicated facility equipped with the necessary personnel and resources. Credit disbursement should occur prior to planting and be realized at the conclusion of the growing season or after crop harvest. The institution must establish a robust monitoring unit to oversee the effective utilization of credit by its beneficiaries. It is important to recognize that the success of such programs may not be universally applicable to other financial institutions, highlighting the need for further research to understand the factors contributing to success or failure within similar environments. Many agricultural credit programs also offer non-credit services to borrowers, aiming to improve productivity and income levels. However, the impact of these non-credit services remains largely unquantified. Future studies should explore how non-credit inputs contribute to the success of borrowers (Islam *et al.*, 2014). This research will provide valuable insights for optimizing agricultural credit programs and enhancing their overall effectiveness in supporting farmers and promoting sustainable agricultural practices.

**Reasonable cost of the produces:** It is recommended that the government increase the current procurement ceiling to at least 10% of total production and directly purchase products from farmers. To facilitate the sale of farmers' produce to the government at fair market rates during the harvest season, an efficient procurement process should be promptly initiated (The

Daily Sun, 2019). Building on the success of initiatives like Shogorip (Shoshsho Gudaam Rin Prokolpo), storage facilities could be established in rural areas to enable farmers to store their products and sell them at higher prices when demand is high. Alternatively, the government can encourage the formation of farmer cooperatives to ensure fair pricing for their produce. Establishing an “Agricultural Prices Commission” to regulate the pricing of farmers’ produce is also recommended. Additionally, restructuring the current food and agricultural value chain is essential to ensure farmers receive a fair profit margin by reducing the role of middlemen (New Age BD, 2020). These measures are crucial for enhancing farmers’ income and promoting agricultural sustainability.

**Strengthening research funding:** Numerous studies demonstrate that investing in agricultural research yields significant profits and benefits (Nagy, 2000). Despite the declining contribution of the agricultural sector to GDP (Chowhan *et al.*, 2023b), the World Bank and FAO have advised the government to increase investment in agricultural research to at least 2% of GDP. This additional funding will undoubtedly incentivize researchers to develop and disseminate solutions that can assist farmers in addressing the potential challenges posed by climate change.

## Conclusions and Recommendations

Over the past few decades, agriculture in Bangladesh has undergone substantial development. The adoption of modern cultivars, mechanized tillage, irrigation practices, and other management strategies has led to an agricultural revolution despite numerous challenges. Traditional subsistence farming has evolved into a more commercialized approach in modern times. Technological advancements and market dynamics have significantly influenced the agricultural sector in Bangladesh. Dedicated research activities have played a crucial role in driving technological progress, as evidenced by the efforts of National Agricultural Research System (NARS) institutes such as BARI, BRRI, BJRI, BSRI, SRDI, BFRI (Fisheries), BFRI (Forest), BTRI, BINA, and BLRI, which have developed high-yielding crop varieties and innovative management technologies. Universities and commercial enterprises have also made substantial contributions to the advancement of science and technology in agriculture. Looking ahead, the biggest challenge for the future of agriculture is to

make agricultural research and extension services more client-oriented and responsive to demand, especially in light of the vulnerabilities posed by climate change. Emphasizing client-driven approaches will be crucial for addressing the evolving needs of farmers and ensuring the resilience of Bangladesh’s agriculture sector in the face of environmental challenges.

For sustainable development in agriculture, a bottom-up participatory technology extension approach and integrated and systems-based research to generate new technologies are advised. Some aspects of agricultural policy must be considered for making significant progress in agriculture, Provide top priority to resource-based and demand-driven research programs with an emphasis on marginal and smallholders and emerging market opportunities; establish a cooperative and target-oriented eco region-wise systems research program for technology development, bridging disciplines and institutions both inside and outside the NARS; and promote sustainable management.

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## Novelty Statement

We did a comprehensive study of agricultural policy and research and development to take future appropriate action by the stakeholders (Govt. and Non-Govt.) for sustainable development of overall agriculture sector of Bangladesh.

## Author’s Contribution

**Sushan Chowhan:** Designed the study, collected literature reviews and reports, and wrote the initial draft of the manuscript.

**Md. Moshir Rahman:** Collected updated statistics and constructed the table and figures.

**Razia Sultana and Md. Abdur Rouf:** checked grammar, language and proofread the article.

**Majharul Islam and Sharmin Ara Jannat:** Organized the references and citations.

All authors read and approved the final manuscript. This work was carried out in collaboration among all authors.

#### *Conflict of interest*

The authors have declared no conflict of interest.

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